

SUBSTRATE USED FOR EXHAUST GAS PURIFICATION AND
METHOD OF FABRICATION THEREOF

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a substrate used for purifying exhaust gas and a method of fabricating the substrate.

10 2. Description of the Related Art

A particulate filter for trapping fine particles in the exhaust gas emitted from the combustion chamber of the internal combustion engine is disclosed in Japanese Unexamined Patent Publication No. 8-508199.

15 This filter has a plurality of passages defined by a plurality of partition walls of a porous material and extending in parallel with each other. One end opening of one of each adjacent two passages is closed, while the other end opening of the other of the adjacent two passages is closed. The exhaust gas that has flowed into a passage of the filter, therefore, flows into adjacent passages through the fine holes of the partition walls.

In the filter described in the publication cited above, the selected openings of the passages are closed by transforming and connecting the end portions of the partition walls into the form of a rectangular pyramid. In closing the end openings of the passages of this filter, a honeycombed structure of a porous material and a jig having a plurality of protrusions are prepared, and the jig is pressed against the end surface of the honeycombed structure so that the protrusions alternately enter the passages of the honeycombed structure.

In the case where the jig is pressed against the end surface of the honeycombed structure to close the openings of the passages by transforming the partition wall ends as described above, however, the partition wall ends may not be sufficiently connected and the openings

of the passages may not be closed up completely. The object of this invention is to positively close up the passage openings of a substrate for purifying the exhaust gas.

5 SUMMARY OF THE INVENTION

In order to solve the problem described above, according to a first aspect of the invention, there is provided a method of fabricating a substrate used for purifying the exhaust gas, comprising:

10 the step of forming a pre-mold including a first end, a second end, a plurality of partition walls extending between the first end and the second end, and a plurality of passages defined by the plurality of the partition walls;

15 the first transforming step for transforming the ends of the partition walls, at the first end of the pre-mold, defining one of each two adjacent passages in such a manner that the ends of the partition walls are collected toward the center of the corresponding passage and connected to each other; and

20 the second transforming step for transforming the ends of the partition walls, at the first end of the pre-mold, in such a manner that the end surface of each of the partition walls at said first end of said pre-mold is depressed toward the center of the end surface.

25 According to a second aspect of the invention, there is provided a method, in the first aspect of the invention, wherein the first transforming step and the second transforming step are executed at the same time.

30 According to a third aspect of the invention, there is provided a method, in the first aspect of the invention, wherein the second transforming step is executed after the first transforming step.

35 According to a fourth aspect of the invention, there is provided a method in the first aspect of the invention, wherein the amount of transformation of the partition wall ends in the first transforming step is

smaller than the minimum amount required to close up a corresponding passage with the same partition wall ends, and the amount of transformation of the partition wall ends in the second transforming step is equal to the
5 difference between the aforementioned minimum required amount and the transformation amount of the partition wall ends in the first transforming step.

According to a fifth aspect of the invention, there is provided a method, in the first aspect of the
10 invention, wherein the amount of transformation of the partition wall ends in the first transforming step is smaller than the minimum amount required to close up a corresponding passage with the same partition wall ends, and the amount of transformation of the partition wall
15 ends in the second transforming step is larger than the difference between the aforementioned required minimum amount and the transformation amount of the partition wall ends in the first transforming step.

According to a sixth aspect of the invention, there is provided a method, in the first aspect of the
20 invention, wherein the cross section of the passages is a square and the partition wall ends closing the corresponding passages each form a portion in the shape of a substantially regular rectangular pyramid.

According to a seventh aspect of the invention, there is provided a method in the first aspect of the
25 invention, wherein the cross section of the passages is a regular triangle and the partition wall ends closing the corresponding passages each form a portion in the shape
30 of a substantially regular hexagonal pyramid.

According to an eighth aspect of the invention, there is provided a method, in the first aspect of the invention, wherein the pre-mold is formed of a porous material.

According to a ninth aspect of the invention, there is provided a method, in the first aspect of the
35 invention, further comprising the third transforming step

for transforming the partition wall ends at the second
end of the pre-mold defining the other of the two
adjacent passages in such a manner that the partition
wall ends are collected toward the center of the
5 corresponding passage and connected to each other, and
the fourth transforming step for transforming the
partition wall ends at the second end of the pre-mold in
such a manner that the end surfaces of the partition
walls at the second end of the pre-mold are depressed
10 toward the center of the end surface.

According to a tenth aspect of the invention, there
is provided a method, in the ninth aspect of the
invention, wherein the first transforming step and the
second transforming step are executed at the same time,
15 and the third transforming step and the fourth
transforming step are executed at the same time.

According to an 11th aspect of the invention, there
is provided a method, in the ninth aspect of the
invention, wherein the second transforming step is
20 executed after the first transforming step, and the
fourth transforming step is executed after the third
transforming step.

According to a 12th aspect of the invention, there
is provided a method in the ninth aspect of the
25 invention, wherein the amount of transformation of the
partition wall ends in the first transforming step is
smaller than the minimum amount required to close up the
passages with the partition wall ends, the amount of
transformation of the partition wall ends in the second
30 transforming step is equal to the difference between the
required minimum amount and the transformation amount of
the partition wall ends in the first transforming step,
the amount of transformation of the partition wall ends
in the third transforming step is smaller than the
35 minimum amount required to close up the passages with the
partition wall ends, and the amount of transformation of
the partition wall ends in the fourth transforming step

is equal to the difference between the required minimum amount and the transformation amount of the partition wall ends in the third transforming step.

5 According to a 13th aspect of the invention, there is provided a method in the ninth aspect of the invention, wherein the amount of transformation of the partition wall ends in the first transforming step is smaller than the minimum amount required to close up the passages with the partition wall ends, the amount of
10 transformation of the partition wall ends in the second transforming step is larger than the difference between the required minimum amount and the transformation amount of the partition wall ends in the first transforming step, the amount of transformation of the partition wall
15 ends in the third transforming step is smaller than the minimum amount required to close up the passages with the partition wall ends, and the amount of transformation of the partition wall ends in the fourth transforming step is larger than the difference between the required
20 minimum amount and the transformation amount of the partition wall ends in the third transforming step.

Further, in order to solve the problem described above, according to a 14th aspect of the invention, there is provided a substrate used for purifying the exhaust
25 gas, comprising a first end, a second end, a plurality of partition walls extending between the first end and the second end, and a plurality of passages defined by the plurality of the partition walls, wherein the ends of a plurality of the partition walls at the first end of the
30 substrate defining one of each two adjacent passages are collected toward the center of a corresponding passage and connected with each other, the end surface of the partition wall ends at the first end of the substrate being depressed toward the center of the end surface, and
35 wherein the ends of a plurality of the partition walls at the second end of the substrate defining the remaining one of the two adjacent passages are collected toward the

center of the corresponding passage and connected with each other, the end surface of the partition walls at the second end of the substrate being depressed toward the center of the end surface.

5 According to a 15th aspect of the invention, there is provided a substrate, in the 14th aspect of the invention, wherein the cross section of the passages is a square in shape and the partition wall ends closing the corresponding passages form a portion substantially in
10 the shape of a regular rectangular pyramid.

 According to a 16th aspect of the invention, there is provided a substrate in the 14th aspect of the invention, wherein the cross section of the passages is a regular triangle in shape and the partition wall ends
15 closing the corresponding passages form a portion substantially in the shape of a regular hexagonal pyramid.

 According to a 17th aspect of the invention, there is provided a substrate in the 14th aspect of the invention, wherein the substrate is formed of a porous
20 material.

BRIEF DESCRIPTION OF THE DRAWINGS

 The present invention may be more fully understood from the description of the preferred embodiments of the invention set forth below together with the accompanying
25 drawings, in which:

 Fig. 1A is a diagram showing an end surface of a substrate according to this invention;

 Fig. 1B is a longitudinal sectional view of the substrate according to the invention shown in Fig. 1A;
30

 Fig 2 is a perspective view showing a part of the end surface of the substrate;

 Fig. 3 is a sectional view along the end surface of the partition walls of the substrate;

35 Fig. 4 is a diagram for explaining a method of fabricating a substrate according to the invention;

 Fig. 5 is a perspective view showing a jig used in a

method of fabricating a substrate according to the invention;

Fig. 6A is a diagram showing the partition walls of the substrate not yet transformed;

5 Fig. 6B is a diagram showing the partition walls of the substrate being transformed;

Fig. 7A is a diagram showing an end surface of a substrate as compared with the substrate according to the invention;

10 Fig. 7B is a longitudinal sectional view of the substrate shown in Fig. 7A;

Fig. 8 is a diagram showing an end surface of a pre-mold used in another embodiment;

15 Fig. 9 is a perspective view of a jig used in another embodiment; and

Fig. 10 is a diagram showing an end surface of the substrate according to another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 This invention will be explained with reference to the drawings. Fig. 1A shows an end surface of a substrate according to a first embodiment, and Fig. 1B is a longitudinal sectional view of the substrate shown in Fig. 1A. The substrate 1 has a honeycombed structure having a plurality of passages 2, 3 extending in parallel
25 with each other. Each passage 2, 3 is defined by a plurality of (four in the first embodiment) partition walls 4. The substrate 1, i.e. the partition walls 4 are formed of a porous material. The substrate 1 is arranged in an exhaust gas passage of the internal combustion
30 engine, for example, and used to trap the fine particles in the exhaust gas emitted from the combustion chamber of the internal combustion engine. The substrate 1 can of course be used as a carrier to carry a catalyst for
35 purifying a specified component of the exhaust gas emitted from the combustion chamber of the internal combustion engine.

In the substrate 1, the passages 2, 3 are closed up

by substantially regular rectangular pyramidal walls 5, 6 at alternate ends. Specifically, two adjacent passages 2, 3 of the substrate 1 are closed up by the substantially regular rectangular pyramidal walls 5, 6 at different ends. The exhaust gas entering the substrate 1, therefore, flows into the passages 2 and further into the adjacent passages 3 through the partition walls 4 as indicated by arrow in Fig. 1B.

The substantially regular rectangular pyramidal walls 5, 6 closing up the passages 2, 3 are each formed by being connected to each other collectively into a depression toward the center (i.e. the center axis of the passages 2, 3) at the ends of the four partition walls 4 defining the passages 2, 3. Specifically, as shown in Fig. 2, the substantially regular rectangular pyramidal walls 5, 6 are formed by being connected to each other into a depression collectively at the end surfaces of the partition walls 4 toward the top T. As shown in Fig. 2, therefore, the strip-shaped wall surfaces defined by the end surfaces of the partition walls 4 extend in the shape of a grid and cross each other to form a depression. Therefore, the end surface defined by the end surfaces of the partition walls 4 of the substrate 1, as shown in the sectional view of Fig. 3, has a convexo-concave shape with a bottom located at a tip T of the substantially regular rectangular pyramidal walls 5, 6 of the substrate 1 and a crest between the tips T.

Next, a method of fabricating a substrate according to the invention will be explained. In the method of fabricating a substrate according to the invention, a pre-mold 10 having a honeycombed structure of a porous material such as cordierite or silicon nitride is formed first as shown in Fig. 4. The pre-mold 10 has a plurality of passages 2, 3 defined by a plurality of partition walls 4 and extending in parallel with each other. The passages 2, 3 have a square cross section.

As shown in Fig. 4, a jig 11 is pressed against the

end surface of the pre-mold 10. The jig 11 has a plurality of protrusions 12 as shown in Figs. 4 and 5. The protrusions 12 each have the shape of a substantially regular rectangular pyramid and are aligned at
5 predetermined intervals. Therefore, strip-shaped wall surfaces 13 extend between the protrusions 12. These strip-shaped wall surfaces 13 are concentrated at a corresponding area A where the bottom corners of the four adjacent protrusions 12 join each other. The strip-
10 shaped wall surfaces 13 are assembled forming a hill toward a corresponding concentrated portion B.

According to this invention, the jig 11 is pressed against the end surface of the pre-mold 10 in such a manner that the protrusions 12 enter passages adjacent to
15 the passages to be closed, i.e. passages other than the passages to be closed. Once the jig 11 begins to be pressed against the end surface of the pre-mold 10, as shown in Fig. 6A, the linearly extending end of each partition wall 4 is transformed by being bent at the
20 central portion thereof toward the center axis C of the passage to be closed, as shown in Fig. 6B. Specifically, the ends of the four partition walls 4 defining each passage to be closed are transformed toward each other so that the forward ends of the partition walls 4 are
25 connected to each other.

The jig 11 further continues to be pressed against the end surface of the pre-mold 10 and, thus, the ends of the partition walls 4 continue to be transformed toward the center axis C of the passage. At the same time, the
30 end surfaces of the partition walls 4 come into contact with the strip-shaped wall surfaces 13 of the jig 11. Thus, the end surfaces of the partition walls 4 are transformed, and are driven into the pre-mold 10 (i.e. the substrate 1) by the wall surface 13. As a result,
35 the end surfaces of the partition walls are transformed into a depression having a deepest portion at the center axis C of the passage. More specifically, according to

this invention, the ends of the partition walls 4 are transformed toward the center axis of the passage, while at the same time transforming the end surface of the partition walls 4 into a depression having a deepest portion at the center axis C of the passage. In this way, the openings of predetermined passages are closed by the substantially regular rectangular pyramidal walls 5, 6.

According to this invention, as compared with the substrate 20 configured as shown in Figs. 7A and 7B, the passages can be positively closed up. This fact will be explained. In the substrate shown in Figs. 7A and 7B, the partition walls 21 defining the passages to be closed are transformed toward the center axis of the corresponding passages while being bent at the central portion thereof. Specifically, the ends of the four partition walls 21 defining a corresponding passage to be closed are transformed toward each other so that the forward ends of the partition walls 21 are connected to each other. In the process, however, the amount by which the forward ends of each partition wall 21 defining the passage to be closed are transformed and are driven into the substrate is substantially equal throughout the forward ends of the partition walls 21, with the result that the forward ends of the partition walls 21 may fail to be sufficiently connected and undesirably form a hole at portions near the center axis of the passage.

According to the invention, in contrast, the amount by which the forward ends of the partition walls 4 defining the passage to be closed are transformed and are driven into the substrate 1 progressively increases toward the center axis C of the passage. As a result, the forward ends of the partition walls 4 are pushed into the substrate 1 to a greater degree, the nearer the center axis C of the passage. Thus, the forward ends of the partition walls 4 are connected sufficiently to each other.

In this invention, as described above, the ends of the partition walls defining each passage to be closed are transformed in such a manner that the particular ends come closer to each other. At the same time, the forward
5 ends of the partition walls are transformed to come still closer to each other and are connected to each other in such a manner that the transformed end surfaces of the partition walls are formed into a depression centered on the center axis of the passage. As an alternative, the
10 ends of the partition walls defining the passage to be closed may be transformed to come closer to each other, followed by transforming the forward ends of the partition walls still closer to each other in such a manner that the end surfaces of the transformed partition
15 walls are formed into a depression centered on the center axis of the passage, thereby connecting the forward ends of the partition walls to each other.

Also, according to the invention, the amount by which the partition wall ends are required to be
20 transformed, to close up the opening of the passage to be closed, can be calculated from the shape (depression in the embodiments described above) of the partition wall ends required to close up the same opening. The partition wall ends thus are transformed by this amount.
25 Specifically, if the step of transforming the partition wall ends closer toward the center axis of the passage is called a first step, and the step of transforming the end surfaces of the transformed partition walls are transformed into a depression centered on the center axis
30 of the passage is called a second step then, in the first step, the partition wall ends are transformed by an amount smaller than the transformation amount calculated above, followed by the second step in which the partition wall ends are transformed by the remainder of the
35 calculated transformation amount by which the same wall ends are left without being transformed in the first step.

The total amount of transformation in the first and second steps may be larger than the calculated transformation amount. In such a case, the partition wall ends are transformed by an amount smaller than the calculated transformation amount in the first step, followed by the second step in which the partition wall ends are further transformed by an amount larger than the remainder of the calculated transformation amount by which the particular partition walls are left without being transformed in the first step. By doing so, the forward ends of the partition walls are transformed and crushed into the same shape.

The invention is also applicable to an exhaust gas purifying substrate fabricated from a pre-mold 10 having the configuration shown in Fig. 8, and to a method of fabricating such a substrate. Specifically, the pre-mold 10 according to the second embodiment shown in Fig. 8 has a plurality of passages 2, 3 defined by a plurality of partition walls 4 and extending in parallel to each other. The passages 2, 3 have a regular triangular cross section. In fabricating an exhaust gas purifying substrate from the pre-mold 10 shown in Fig. 8, a jig 11, shown in Fig. 9, is used. The jig 11 has a plurality of protrusions 12 substantially in the shape of a truncated regular hexagonal pyramid. The protrusions 12 are arranged in alignment at predetermined spatial intervals. Therefore, a strip-shaped wall surface 13 extends between adjacent protrusions 12. These strip-shaped wall surfaces 13 join each other in an area A where the bottom corners of three adjacent protrusions 12 are concentrated. These strip-shaped wall surfaces 13 are concentrated in such a manner as to be protruded toward the concentrated portion B.

The jig 11 is pressed against the end surface of the pre-mold 10 in such a way that a passage adjoining each passage to be closed, i.e. a passage other than to be closed, is entered by the corresponding protrusion 12.

Once the jig 11 begins to be pressed against the end surface of the pre-mold 10, the ends of the partition walls 4 are transformed toward the center axis of the passage by the protrusions 12 while being bent at the central portion thereof. Specifically, the ends of the three partition walls 4 defining each passage are transformed to come closer to each other, so that the forward ends of the partition walls 4 are connected to each other.

The jig 11 then continues to be pressed against the end surface of the pre-mold 10, and thus the ends of the partition walls 4 continue to be transformed toward the center axis of the passage. At the same time, the end surfaces of the partition walls 4 come into contact with the strip-shaped wall surfaces 13 of the jig 11, whereby the end surfaces of the partition walls 4 are transformed and are driven into the pre-mold 10 (i.e. the substrate). In this way, the end surface of each partition wall 4 is transformed into a depression having a deepest portion at the center axis (tip T of a substantially regular hexagonal wall) of the passage. Thus, the openings of predetermined passages are closed up by the substantially regular hexagonal walls.

The matters explained regarding the first embodiment can be applied also to the second embodiment. Also, the ratio of the amount required to transform the partition wall end toward the center axis of a given passage having a regular triangular cross section to close the particular passage relative to the length of one side of each passage, i.e. relative to the width of the partition walls defining the particular passage, is smaller than a similar ratio of the amount required to transform the partition wall end toward the center axis of the passage having a regular triangular cross section to close the same passage relative to the length of one side of each passage. In this case, the breakage of the partition wall ends during the transformation thereof is

suppressed. The second embodiment, therefore, as compared with the first embodiment, has the advantage of a smaller chance of the partition wall ends being broken during the transformation thereof.

5 This invention is of course not limited to an exhaust gas purifying substrate fabricated from a pre-mold configured of passages having a square cross section or a regular triangular cross section and a method of fabrication thereof. Alternatively, the invention is
10 also applicable to an exhaust gas purifying substrate fabricated from a pre-mold configured of passages having a cross section of a polygon such as a rectangle, triangle or hexagon and a method of fabrication thereof. Also in the embodiments described above, the jig having
15 substantially regular square pyramidal protrusions may alternatively have truncated and substantially regular hexagonal protrusions. Further, a jig having truncated and substantially regular hexagonal protrusions may be replaced with a jig having substantially regular
20 hexagonal protrusions with sharp tips.

According to this invention, the forward ends of the partition walls are transformed to come close to each other and connected to each other without fail

25 While the invention has been described by reference to specific embodiments chosen for purposes of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.